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ExoBoost: Enhancing Agricultural Resilience with Microbe's Exopolysaccharides

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Abstract

Drought stress poses a significant threat to global agricultural productivity, necessitating innovative strategies to mitigate its adverse effects on crop yields. There is rising interest in employing stress-resilient PGPR (Plant Growth Promoting Rhizobacteria) as microbial biostimulants to bolster crop productivity in drought-affected agro ecosystems. Leveraging the bioactivity of biostimulants derived from Exopolysaccharides Producing Rhizobacteria (EPR) offer promising avenues for sustainable agriculture in water-limited environments. These biostimulants act as multifunctional agents, facilitating water uptake, improving soil structure, and promoting nutrient absorption, thereby mitigating the detrimental effects of drought stress on crop growth and productivity. These EPR establish symbiotic interactions with plants, augmenting the plant's adaptive responses to water scarcity by modulating hormone levels, and activating stress-responsive pathways. Moreover, the development of comprehensive production strategies that integrate techniques to mitigate the impacts of drought is imperative to ensure a sustainable and reliable food supply. EPR emerges as a promising strategy for addressing the challenges posed by drought stress in agriculture. These biostimulants offer sustainable solutions to enhance crop resilience, secure food security, and promote environmental sustainability amidst climate change-induced water scarcity.

Keywords: EPR; Rhizobacteria; Bio-Stimulants; Plant; Exopolysaccharide

Abbreviations: EPS: Exopolysaccharide; PGPR: Plant Growth-Promoting Rhizobacteria; ROS: Reactive Oxygen Species; ACC: 1-Aminocyclopropane-1-Carboxylate; IAA: Indole-3-Acetic Acid; ABA: Abscisic Acid; EPR: Exopolysaccharides Producing Rhizobacteria

Introduction

In the ever-evolving world of agriculture, farmers are continually seeking innovative solutions to enhance crop resilience, increase yields, and mitigate the impact of environmental stressors. One promising avenue gaining traction is the use of microbial biostimulants, specifically those capable of producing extracellular polymeric substances. Exopolysaccharides (EPS) are extracellular polymers secreted by various microorganisms, renowned for their ability to enhance soil structure, water retention, and nutrient availability [1]. The production of EPS producing plant growth-promoting rhizobacteria (PGPR) has demonstrated promising effects in reducing the drought stress on crops. When there is insufficient water availablility, these EPS producing rhizobacteria can enhance plant growth and development [2]. These bacteria ensures the plant's survival during a drought while simultaneously fostering the plant's growth through a number of strategies, such as enhanced phytohormone production, osmotic adjustments, and antioxidant activity. The EPS producing rhizobacteria are believed to possess the capacity to enhance drought resistance in plants through diverse mechanisms, such as bolstering drought tolerance and resilience, which induce physiological and biochemical alterations. These modifications result in adjustments to the plant's phytohormonal levels and the protection through antioxidants [3]. These defense mechanisms can lead to notable alterations in the structural and functional characteristics of plants, enhancing their ability to withstand abiotic stress. The EPS producing rhizobacteria accomplish this primarily by exhibiting a stress response akin to that of heat-stressed plants during periods of water deficit or elevated temperatures [4]. These innovative approaches have enabled the isolation and characterization of potent EPS producing PGPR strains, paving the way for the formulation of biostimulant products optimized for drought resilience. This is a novel approach by EPS-producing biostimulants as potential candidate to bolster crop productivity and resilience under drought stress conditions. Continued research and application efforts are warranted to fully realize the potential of EPR in optimizing crop production systems in water-limited environments.

EPS Producing Plant Growth Promoting Rhizobacteria

PGPR are capable of producing a wide range of bioactive compounds such as EPS, these bioactive compounds may help in mitigation the effects of drought stress in agricultural crops [5]. EPS are important compounds that benefit microbes in a number of physiological aspects and offer a protective environment against stressful situations such as drought, salt, temperature, or heavy metal pollution [6,7]. Unlike traditional fertilizers or pesticides, biostimulants work symbiotically with plants, harnessing the power of beneficial microorganisms to promote overall plant health and resilience. Microbial biostimulants decreases the damage of cell's internal organelle (cell membrane and plastids) and also assisted the plants in overcoming the deficiencies of macronutrients (Calcium, Magnasium and Potassium) and micronutrients (Copper, Manganese, Iron and Zinc) triggered due to water stress [8]. In addition, they alter metabolic pathways that include phytohormones, flavonoids, phenolic acids, and amino acids, all of which improve resistance to drought stress. Biostmulants positively influence physiological and metabolic events, including photosynthetic activity, phytohormonal balances, nutrient acquisition, and scavenging of reactive oxygen species, that can also help plants to cope with drought and salinity stress [9,10].

The Function of EPR in Tolerance to Stress

Extracellular polymeric substances are complex molecules of polysaccharides, carbohydrates, structural proteins, enzymes, amino sugars, pyruvates, glycoproteins, lipids, extracellular DNA, and certain humic substances. It is secreted by certain microorganisms, primarily bacteria and fungi that play a crucial role in environmental adaptation and microbial community dynamics. Here are some points highlighting the contribution of bacteria in mitigating abiotic stress in plants.

Boost Water Availability: In water deficient condition EPS play essential role in water conservation. EPS secreted by rhizobacteria have special cementing property to promote the soil aggregation, water holding capacity and enhancing soil water retention. These EPR improve soil water permeability, which increases plant cells availability and movement of water. They have the ability to stabilize soil, thereby reducing runoff and enhancing plant water availability [11].

Strengthen Plant Antioxidant Activity: EPR increases the concentration of antioxidant molecules like phenolics, flavonoids, and carotenoids in plant and enhance the activity of enzymes involve in production of antioxidants such as ascorbate peroxidase, superoxide dismutase, guaiacol peroxidase, and other antioxidative enzymes all performed better in the presence of EPS. These bacteria also assist in scavenging Reactive Oxygen Species (ROS) and free radicals such as hydroxyl radical [12].

Increase Nutrient Absorption Efficiency: EPR plays a pivotal role in enhancing the absorption of essential nutrients. By increasing water permeability, they facilitate the passage of nutrients through the roots. Moreover, the the bacteria situated at the root surface synthesize specific ion fluxes from the surrounding environment, thereby augmenting the uptake of paticular nutrients and minerals [13].

Accumulation of Osmolytes: EPR facilitate osmolyte accumulation, which can raise plant cell osmotic pressure and enhancing their ability to swell, thereby safeguarding against damage. Additionally, these osmolytes assist in the removal of free radicals, mitigating the potential harm to cell membranes caused by their accumulation during drought stress [14].

Hormonal Balance Regulation: Certain EPR mediate the hormonal balance regulation in plant by modifying root structure, increasing 1-aminocyclopropane-1-carboxylate (ACC) activity, and producing various plant hormones, Indole-3-acetic acid (IAA), Gibberellic acid and Cytokinins. Additionally, they also produce the Abscisic acid (ABA), which partially closes the stomata and reducing transpiration rates [15].

Enhance Plant Growth and Development: EPR plays a multifaceted role in soil enhancement and plant growth. The EPS produced by these EPR create a protective rhizosheath around the root, effectively preventing root desiccation for extended periods. Additionally, they improve soil aggregation, raise water permeability, and accelerate nutrient absorption at the root, thereby fostering robust root and shoot growth. These all activity promotes an increase plant biomass, chlorophyll content and leaf surface area [2].

Challenges Using EPR

Although microbial biostimulants hold considerable potential, numerous challenges remain. These include refinement of formulation and application techniques, ensuring consistency and efficacy of products, and navigating regulatory barriers. Furthermore, further research is needed for more research to comprehensively grasp the intricate interplay among microbial biostimulants, host plants, and the environment. This deeper understanding will pave the way for the creation of customized solutions tailored to diverse crops and varying growing conditions.

Future Possibilities and Conclusion

The need for sustainable farming techniques is greater than ever as the world's population continues to rise and environmental challenges increase. Through leveraging microbial biostimulants that produce EPS, farmers can cultivate robust crops capable of flourishing despite challenges. By harnessing the power of microbial biostimulants with EPS production, farmers can cultivate resilient crops capable of thriving in the face of adversity. This innovative approach not only holds the key to increasing agricultural productivity and food security but also offers a glimpse into a future where agriculture and nature work in harmony to sustainably feed the world.

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